JC11 Rec'd PCT/PTO 09 MAR 200

FORM PTO-1390 (REV. 5-93) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**	ATTORNEY'S DOCKET NUMBER **2345/144** U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/786837

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED:
PCT/EP00/05367	**10 June 2000 (10.06.00)**	**9 July 1999 (09.07.99)**

TITLE OF INVENTION
METHOD AND DEVICE FOR FORMING THE INTENSITY PROFILE OF A LASER BEAM

APPLICANT(S) FOR DO/EO/US
Wolfgang DULTZ, Leonid BERESNEV, Rosemarie HILD and Bernhard HILS

Applicant(s) herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) immediately rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☒ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)) UNSIGNED.
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A **FIRST** preliminary amendment.
    ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
14. ☒ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information: International Search Report, Form PCT/RO/101. PCT International Publication

Express Mail No.:EL302703314US

NY01 355699 v 1

JC02 Rec'd PCT/PTO 09 MAR 2001

U.S. APPLICATION NO. (if known, see 37 C.F.R. 1.5) 09/786837	INTERNATIONAL APPLICATION NO. PCT/EP00/05367	ATTORNEY'S DOCKET NUMBER 2345/144

	CALCULATIONS	PTO USE ONLY
17. ☒ The following fees are submitted: **Basic National Fee (37 CFR 1.492(a)(1)-(5)):** Search Report has been prepared by the EPO or JPO .... $860.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) ...... $690.00 No international preliminary examination fee paid to USPTO (37 CFR 1.482) but international search fee paid to USPTO (37 CFR 1.445(a)(2)) .... $710.00 Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $1,000.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 860	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

Claims	Number Filed	Number Extra	Rate		
Total Claims	10 - 20 =	0	X $18.00	$0	
Independent Claims	2 - 3 =	0	X $80.00	$0	
Multiple dependent claim(s) (if applicable)			+ $270.00	$	

TOTAL OF ABOVE CALCULATIONS =	$860	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).	$	
SUBTOTAL =	$860	
Processing fee of $130.00 for furnishing the English translation later the ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$860	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +	$	
TOTAL FEES ENCLOSED =	$860	
	Amount to be refunded charged	$ $

a. ☐ A check in the amount of $________________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 11-0600 in the amount of $860.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 11-0600. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

By [signature] R No 35,952

[signature]
SIGNATURE

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3/9/01
DATE

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PATENT TRADEMARK OFFICE

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JC02 Rec'd PCT/PTO 0 9 MAR 2001

[2345/144]

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s)	:	Wolfgang DULTZ et al.
Serial No.	:	To Be Assigned
Filed	:	Herewith
For	:	METHOD AND DEVICE FOR FORMING THE INTENSITY PROFILE OF A LASER BEAM
Examiner	:	To Be Assigned
Art Unit	:	To Be Assigned

Assistant Commissioner for Patents
Washington, D.C. 20231

PRELIMINARY AMENDMENT

SIR:

Kindly amend the above-identified application before examination, as set forth below.

IN THE TITLE:

Please replace the title with the following:

--METHOD AND DEVICE FOR FORMING THE INTENSITY PROFILE OF A LASER BEAM--.

IN THE SPECIFICATION:

Please amend the specification, including abstract, pursuant to the attached substitute specification. Also attached is a red-lined copy of the specification, indicating deleted and added sections. No new matter has been added.

EL302703314

IN THE CLAIMS:

Please cancel claims 1-11 without prejudice.

Please add the following new claims:

12. (New) A method for forming the intensity profile of a laser beam, comprising:
providing the laser beam so that the laser beam strikes an optically addressable spatial light modular, the optically addressable spatial light modular having at least one of a local transmission property and a reflection property depending nonlinearly on a local illumination intensity.

13. (New) The method as recited in claim 12, wherein the at least one of the local transmission property and the reflection property of the optically addressable spatial light modular has a saturation range, an at least one of a locally transmitted intensity and a reflected intensity of the laser beam in the saturation range is substantially independent of a locally incident intensity of the laser beam outside the saturation range.

14. (New) The method as recited in claim 13, wherein the intensity of the laser beam to be formed is adapted to the saturation range of the optically addressable spatial light modular by at least one of a widening of the laser beam and an optical filter.

15. (New) The method as recited in claim 13, further comprising inserting an optical imaging system into an optical path of rays for beam widening, the optically addressable spatial light modular being located in the optical path of rays.

16. (New) The method as recited in claim 15, wherein the optical imaging system includes a first telescope imaging system and a second telescope imaging system designed as an at least one of a mechanically adjustable zoom system, an electrically adjustable zoom system, a mechanically controllable zoom system, and

an electrically controllable zoom system, the widening of the laser beam being an at least one of variable and adaptable to an intensity change.

17. (New) The method as recited in claim 12, wherein the optically addressable spatial light modular is a liquid crystal modulator.

18. (New) The method as recited in claim 12, wherein the optically addressable spatial light modular is partitioned into an at least one zone, the at least one zone being configured to be electrically driven to alter the at least one of the local transmission property and the reflection property of the optically addressable spatial light modular.

19. (New) A device for forming at least one of an intensity profile of a laser beam and a homogeneous intensity profile of the laser beam, comprising:

an optically addressable spatial light modular, the optically addressable spatial light modular having at least one of a local transmission property and a reflection property depending nonlinearly on at least one of a local illumination intensity and a telescope imaging system, configured to spatially widen the laser beam.

20. (New) The device as recited in claim 19, wherein the optically addressable spatial light modular is a liquid crystal modulator.

21. (New) The device as recited in claim 19, wherein the optically addressable spatial light modular has at least one zone which is able to be electrically driven to alter the at least one of the local transmission property and the reflection property of the optically addressable spatial light modular.

REMARKS

This Preliminary Amendment cancels, without prejudice, original claims 1-11 in the underlying PCT Application No. PCT/EP00/05367, and adds new claims 12-

21. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

The amendments to the specification and abstract reflected in the substitute specification are to conform the specification and abstract to U.S. Patent and Trademark Office rules, and do not introduce new matter into the application.

The underlying PCT Application No. PCT/EP00/05367 includes an International Search Report, issued October 6, 2000, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

Applicants assert that the present invention is new, non-obvious, and useful. Prompt consideration and allowance of the claims are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

By: Reg No 35,952

Dated: 3/9/01

By:

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~~METHOD AND DEVICE FOR FORMING~~ THE INTENSITY PROFILE OF A LASER BEAM

Field of the Invention

The present invention relates to a method and a device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, as well as to the use of an optically addressable spatial light modulator (OASLM) for forming the intensity profile of a laser beam.

Background of the Invention

The physical properties of laser light differ fundamentally from those of conventional light sources. Laser light is coherent and can be produced as a light beam having a small, even if finite aperture angle. This narrow beam concentration is particularly advantageous for illumination and imaging purposes, since the wave fronts of the laser light approach the ideal of plane waves. They can be transformed into spherical wave fronts and can be utilized for highly resolving, diffraction-limiting focusing.

One drawback of the laser beam is its Gaussian character, which is determined by the manner in which light is generated in the resonator. The intensity distribution of the light transversely to the beam has the shape of a Gaussian bell curve. This means that the intensity is at a maximum in the middle of the beam, and it then drops

off exponentially toward the edges.

This is a drawback in image processing and projection technologies which require illuminating flat photomasks. However, it is also a drawback in interferometry, where one desires a most uniform possible illumination of the lighted surface. Such uniformity is not provided when working with a Gaussian intensity profile. In material processing as well, such as in medical applications involving heating of tissue, or in laser welding, uniform heating is required over the entire width of the laser beam or of the illuminated surface. Such uniform heating cannot be attained when working with a Gaussian shaped illumination and, thus, for instance, a Gaussian energy deposition. For that reason, the cross-sectional profile of the light beam should be as rectangular as possible for the areas of application mentioned. The spatial intensity profile should be homogeneous, i.e., more or less constant over a certain width. To effect this, in practice, the beam is widened and one then works only with the more or less homogeneous inner beam region with the outer region being masked out. However, this can lead to significant intensity losses.

Since the actual laser system, the optical amplification medium in the resonator, is not readily accessible to the user, the forming of the beam into a rectangular profile must take place outside of the laser. For this purpose, optical filters, so-called "bull's eye" filters are known, which attenuate the laser beam more vigorously in the middle than at the edges, thereby flattening the bell shape of the beam profile to a virtually rectangular profile. For the most part, these filters are made of a

transparent plate, e.g., a glass plate, upon which a more or less reflective coating, for example a metal, is coated by vapor deposition. The desired beam profile is produced by properly selecting the locally dependent optical density, i.e., the local transmission and reflection properties. These filters are static and, therefore, can only be used for a specific laser having a fixed, known intensity profile. When the laser changes its profile, e.g., due to fluctuations or manifestations of aging, the filters undesirably alter the shape of the profile, since they are no longer adapted to the laser data. Another disadvantage associated with reflecting filters of this kind is that unevenly reflected laser light has a reactive effect on the laser and can degrade its stability. Moreover, in place of reflecting filters, it is also generally known to use holographic filters for forming beams. See, for example, I. Gur et al.: Diffraction limited domain flat-top generator; Opt. Communications 145, 237 (1998), incorporated herein by reference. These filters are also static and are not responsive to time-related changes in the laser beam profile. Also problematic is the fact that the rectangular profile is only produced in the imaging plane of the holographic element.

Summary of the Invention

The present invention provides a device and method for forming the most homogeneous possible, rectangular beam profile from any initial intensity profile. The present invention further provides a device and method for forming the most homogeneous possible, rectangular beam profile for a Gaussian beam profile, so that, among other

things, the formed beam profile can be substantially stable with respect to fluctuations in the incident intensity profile and in the light intensity.

The present invention further provides a method for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, the laser beam striking an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity.

An embodiment of the present invention provides a device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, is composed of an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity, as well as of at least one telescope imaging system, which is capable of spatially widening the laser beam.

Some embodiments of the present invention further provide using an optically addressable spatial light modular (OASLM) for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile.

Some embodiments of the present invention further provide a beam former, i.e., a method for forming beams, where the formed intensity profile is stabilized with respect to changes in the original intensity profile through the use of an active or adaptive optical element having optical properties that are dependent upon the local

illumination intensity. An optical element can be used whose local transparency changes with the local illumination intensity. A defined beam profile, which is virtually independent of fluctuations in the initial intensity distribution, is automatically produced. This can also be done without any additional controlling external influence. For that reason, the method and the beam former, respectively, can be used for any laser systems at all, and only need to be adapted to a minor degree to prevailing conditions.

An embodiment of the present invention further provides that the optically non-linear element is an optically addressable spatial light modulator (OASLM) or a liquid crystal light valve. The optically non-linear element can be driven in the saturation range to produce a homogeneous (rectangular) laser beam profile; the locally transmitted intensity can then independent of the local illumination intensity.

Optically addressable spatial light modulators (OASLM) are known, for example, from "Spatial Light Modulators; OSA - Technical Digest ISBN 155752-494-7 Washington 1997, hereby incorporated by reference herein, which are made of a photoconductive layer and of an electro-optical, voltage-sensitive layer. In response to local irradiation, the voltage in the photoconductor breaks down locally and is transferred to the electro-optical layer. On a localized basis, this alters the transmission or reflection characteristics of the electro-optical layer, which, in turn, is now optically indicative of the irradiation. The photoconductive layer must be sensitive to the wavelength of the incident light. The electro-

optical layer is, for example, a liquid crystal, which has optical modulator properties within broad spectral ranges. Certain materials unite the properties of the photo-sensitive and voltage-sensitive layer, such as photorefractive crystals or polymers (Spatial Light Modulators; OSA - Technical Digest ISBN 155752-494-7 Washington 1997, M. Petrov et al.: Photorefractive Crystals, Berlin 1991).

The present invention provides liquid crystals which can have nonlinear optical properties and can be used in OASLMs. In the present invention, the OASLM can be based, for example, on nematic or helical smectic liquid crystals, the latter having an operating frequency of 10^2 to 10^3 Hz, thereby facilitating faster reactions to output profile changes than do elements based on nematic liquid crystals (switching times in the range of 10^{-2} s). The modulation properties of these liquid crystals depend nonlinearly on the applied voltage and, thus, on the local illumination intensity 1 on the photoconductor.

In the present invention, a transmission characteristic of an OALSM of this kind may be exemplified by a linear relation between the illumination intensity and transmitted intensity for low illumination intensities, as well as by a transition into the saturation range, where the transmitted intensity is virtually independent of the illumination intensity. For higher intensities, the transmitted intensity can again depend more heavily on the illumination intensity.

The properties of the OASLM in the present invention can thus enable high light intensities to be attenuated more

vigorously than low intensities. In this manner, the intensity of a Gaussian beam in the center can be suppressed as compared to the edge regions, and the transmitted intensity approaches a rectangular shape having a flat plateau in the center.

Another embodiment of the present invention provides that the OASLM layers undergo pattern delineation. A further embodiment provides that the OASLM layers are resolved into individual zones, in particular optical points (pixels), and in a possible embodiment of the present invention, can be capable of being driven individually. This diminishes crosstalk between nearby picture elements. This permits electrical intervention in the modulator, on a pixel-by-pixel basis, in particular an adaptation of the local transmission properties, targeted to the initial intensity profile. One can regulate the driving of the individual zones by measuring the shaped beam profile and examining it for deviations from a nominal form, in particular from the rectangular form. By way of a feedback path, the magnitude of the local deviations is then used as a basis for adapting the transmission properties of the zones or of the picture elements of the OASLM.

In some embodiments of the present invention, to work in the saturation region of the OASLM, the intensity of the laser beam to be shaped can be preferably adapted by widening the beam and/or through the use of optical filters at the saturation region of the OASLM. For purposes of beam widening, an optical imaging system can be preferably inserted into the optical path of rays, within which the OASLM is located. The optical imaging

system can encompass two telescope imaging systems, preferably designed as mechanically or electrically adjustable or controllable zoom systems. Thus, the beam widening can be variable, so that changes in intensity can always be compensated by intensity fluctuations of the laser or by replacing the laser.

Brief Description of the Drawings

Figure 1	shows a typical transmission characteristic of an OASLM in accordance with the present invention;
Figure 2a	shows an embodiment of the present invention for forming a beam with the use of an OASLM;
Figure 2b	shows another embodiment of the present invention for forming a beam with the use of an OASLM; and
Figure 2c	shows another embodiment of the present invention for forming a beam, with the use of an OASLM.

Detailed Description

Figure 1 schematically depicts a typical transmission characteristic of an OASLM, as used in accordance with the present invention, the incident intensity being plotted on the x-axis and the transmitted intensity on the y-axis. For low intensities, the OASLM has a substantially linear transmission characteristic, for example, it is essentially transparent to the incident radiation. For higher incident intensities, the transmitted intensity is substantially independent of the

incident intensity; this saturation range is selected as the working range for the beam formation. The intensity of the incident laser beam to be formed can be adapted to this working range by filters or by widening the beam. In this context, by widening the beam, once it has passed through the OASLM, the light is able to be focused again and there is minimal loss of total intensity.

Three set-ups are shown in Figures 2a-c for forming a beam in accordance with the present invention, using an OASLM. Figure 2a illustrates a set-up where the OASLM is inserted between two coupler telescopes 1, 2, into the laser's path of rays. Telescopes 1, 2 each include two lenses having focal lengths f_1, f_2 and f_1', f_2', respectively, arranged at a distance of f_1+f_2 and $f_1'+f_2'$, respectively. The telescopes can be used for beam widening, to reduce the intensity in the laser beam center to the point where it coincides with the plateau region of the characteristic in accordance with Figure 1. The laser beam having the flattened beam profile exits the second telescope 2 to the right. If it is necessary to simultaneously widen the beam, the right telescope 2 must have a smaller magnification than the left telescope 1.

In certain cases, for example, once a laser is coupled into an optical fiber, the laser intensity can already be optimally adapted to the OASLM. Without any previous widening, the light can then be directly conducted to the OASLM, as shown in Figure 2b. The light from fiber 3 then falls directly on beam former OASLM, which can be in optical contact with fiber 3. Reflection losses experienced during the transition into the OASLM, are

able to be kept to a minimum in this case by using an oil to adapt the refraction index. Thus the OASLM can have an especially small type of construction in this embodiment of the present invention.

When heavy fluctuations in laser intensity is being experienced, or when the intention is to use the same beam former for different types of lasers, it is recommended to connect two zoom telescopes 5, 6 instead of telescopes having fixed magnifications, as in Figure 2a. A possible embodiment of this is shown schematically in Figure 2c. In this case, the beam widening can be altered and, given electrically adjustable zoom telescopes, also controlled.

The present invention has many diverse industrial applications. The present invention can be employed in applications where the most uniform possible illumination of surfaces by laser light is critical, especially when working with image processing and projection technology, in interferometry, as well as in material processing where the use of lasers is required.

Abstract

The present invention relates to a method and a device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile. In an embodiment of the present invention, the laser beam can strike an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity.

METHOD AND DEVICE FOR FORMING THE INTENSITY PROFILE OF A LASER BEAM

[Technical]
<u>Field of the Invention</u>

The present invention relates to a method and a device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, as well as to the use of an optically addressable spatial light modulator (OASLM) for forming the intensity profile of a laser beam.

<u>Background of the Invention</u>

The physical properties of laser light differ fundamentally from those of conventional light sources. Laser light is coherent and can be produced as a light beam having a small, even if finite aperture angle. This narrow beam concentration is particularly advantageous for illumination and imaging purposes, since the wave fronts of the laser light approach the ideal of plane waves. They [are very easily] <u>can be</u> transformed into spherical wave fronts and can be utilized for highly resolving, diffraction-limiting focusing.

One drawback of the laser beam is its Gaussian character, which is determined by the manner in which light is generated in the resonator. The intensity distribution of the light transversely to the beam has the shape of a Gaussian bell curve. This means that the intensity is at a maximum in the middle of the beam, and it then drops off exponentially toward the edges.

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MARKED UP VERSION OF SPECIFICATION

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This is [particularly disadvantageous]a drawback in image processing and projection technologies which require illuminating flat photomasks. However, it is also a drawback in interferometry, where one desires a most uniform possible illumination of the lighted surface[is critical]. Such uniformity is not provided when working with a Gaussian intensity profile. In material processing as well, such as in medical applications involving heating of tissue, or in laser welding, uniform heating is required over the entire width of the laser beam or of the illuminated surface. Such uniform heating cannot be attained when working with a Gaussian shaped illumination and, thus, for instance, a Gaussian energy deposition. For that reason, the cross-sectional profile of the light beam should be as rectangular as possible for the areas of application mentioned. The spatial intensity profile should be homogeneous, i.e., more or less constant over a certain width. To effect this, in practice, the beam is widened and one then works only with the more or less homogeneous[,] inner beam region[,] with the outer region being masked out. However, this can lead[s] to significant intensity losses.

Since the actual laser system, the optical amplification medium in the resonator, is not readily accessible to the user, the forming of the beam into a rectangular profile must take place outside of the laser. For this purpose, optical filters, so-called "bull's eye" filters are known, which attenuate the laser beam more vigorously in the middle than at the edges, thereby flattening the bell shape of the beam profile to a virtually rectangular profile. For the most part, these filters are made of a transparent plate, e.g., a glass plate, upon which a more or less reflective coating, for example a metal, is coated by vapor deposition. The desired beam profile is

produced by properly selecting the locally dependent optical density, i.e., the local transmission and reflection properties. These filters are static and, therefore, can only be used for a specific laser having a fixed, known intensity profile. When the laser changes its profile, e.g., due to fluctuations or manifestations of aging, the filters undesirably alter the shape of the profile, since they are no longer adapted to the laser data. Another disadvantage associated with reflecting filters of this kind is that unevenly reflected laser light has a reactive effect on the laser and can degrade its stability. Moreover, in place of reflecting filters, it is also generally known to use holographic filters for forming beams[(]. See, for example, I. Gur et al.: Diffraction limited domain flat-top generator; Opt. Communications 145, 237 (1998)[)], incorporated herein by reference. These filters are also static and are not responsive to time-related changes in the laser beam profile. Also problematic is the fact that the rectangular profile is only produced in the imaging plane of the holographic element.

[Technical Objective

The underlying objective]Summary of the Invention

The present invention [is, therefore, to form]provides a device and method for forming the most homogeneous possible, rectangular beam profile from any initial intensity profile[at all, in particular from]. The present invention further provides a device and method for forming the most homogeneous possible, rectangular beam profile for a Gaussian beam profile, [the intention being for]so that, among other things, the formed beam profile [to]can be substantially stable with respect to

fluctuations in the incident intensity profile and in the light intensity.

[

Detailed Description of the Invention

The objective is achieved by a method]The present invention further provides a method for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, the laser beam [ ]striking an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity.

[A device in accordance with]An embodiment of the present invention provides a device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, is composed of an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity, as well as of at least one telescope imaging system, which is capable of spatially widening the laser beam.

[Furthermore, the objective is achieved by the use of]Some embodiments of the present invention further provide using an optically addressable spatial light modular (OASLM) for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile.

[T]Some embodiments of the present invention further provide[s] a beam former, i.e., a method for forming beams, where the formed intensity profile is stabilized with respect to changes in the original intensity profile

through the use of an active or adaptive optical element having optical properties that are dependent upon the local illumination intensity. [In particular, a]An optical element [is]can be used[,] whose local transparency changes with the local illumination intensity. A defined beam profile, which is virtually independent of fluctuations in the initial intensity distribution, is automatically produced. [In principle, t]This [is]can also be done without any additional controlling external influence. For that reason, the method and the beam former, respectively, can be used for any laser systems at all, and only need to be adapted to a minor degree to prevailing conditions.

[In accordance with]An embodiment of the present invention[,] further provides that the optically non-linear element is an optically addressable spatial light modulator (OASLM) or a liquid crystal light valve. [It is preferably]The optically non-linear element can be driven in the saturation range to produce a homogeneous (rectangular) laser beam profile; the locally transmitted intensity [is]can then independent of the local illumination intensity.

Optically addressable spatial light modulators (OASLM) are known, for example, from "Spatial Light Modulators; OSA - Technical Digest ISBN 155752-494-7 Washington 1997["], hereby incorporated by reference herein, which are made of a photoconductive layer and of an electro-optical, voltage-sensitive layer. In response to local irradiation, the voltage in the photoconductor breaks down locally and is transferred to the electro-optical layer. On a localized basis, this alters the transmission or reflection characteristics of the electro-optical layer, which, in turn, is now optically indicative of the

irradiation. The photoconductive layer must be sensitive to the wavelength of the incident light. The electro-optical layer is, for example, a liquid crystal, which has optical modulator properties within broad spectral ranges. Certain materials unite the properties of the photo-sensitive and voltage-sensitive layer, such as photorefractive crystals or polymers (Spatial Light Modulators; OSA - Technical Digest ISBN 155752-494-7 Washington 1997, M. Petrov et al.: Photorefractive Crystals, Berlin 1991).

[In accordance with t]The present invention[,] provides liquid crystals which can have nonlinear optical properties [are]and can be used in OASLMs. [T]In the present invention, the OASLM [is]can be based, for example, on nematic or helical smectic liquid crystals, the latter having an operating frequency of 10^2 to 10^3 Hz, thereby facilitating faster reactions to output profile changes than do elements based on nematic liquid crystals (switching times in the range of 10^{-2} s). The modulation properties of these liquid crystals depend nonlinearly on the applied voltage and, thus, on the local illumination intensity 1 on the photoconductor.

[A typical]In the present invention, a transmission characteristic of an OALSM of this kind [is]may be exemplified by a linear relation between the illumination intensity and transmitted intensity for low illumination intensities, as well as by a transition into the saturation range, where the transmitted intensity is virtually independent of the illumination intensity. For higher intensities, the transmitted intensity can again depend more heavily on the illumination intensity.

The [above described]properties of [an]the OASLM in the

present invention can thus enable[, in particular,] high light intensities to be attenuated more vigorously than low intensities. In this manner, the intensity of a Gaussian beam in the center [is]can be suppressed as compared to the edge regions, and the transmitted intensity approaches a rectangular shape having a flat plateau in the center.

[One advantageous further refinement]Another embodiment of the present invention provides [for]that the OASLM layers[to] undergo pattern delineation[, preferably]. A further embodiment provides that the OASLM layers are resolved into individual zones, in particular optical points (pixels), [preferably]and in a possible embodiment of the present invention, can be capable of being driven individually. This diminishes crosstalk between nearby picture elements. [Finally, t]This permits electrical intervention in the modulator, on a pixel-by-pixel basis, in particular an adaptation of the local transmission properties, targeted to the initial intensity profile. One can[advantageously] regulate the driving of the individual zones by measuring the shaped beam profile and examining it for deviations from a nominal form, in particular from the rectangular form. By way of a feedback path, the magnitude of the local deviations is then used as a basis for adapting the transmission properties of the zones or of the picture elements of the OASLM.

[T]In some embodiments of the present invention, to work in the saturation region of the OASLM, the intensity of the laser beam to be shaped [is]can be preferably adapted by widening the beam and/or through the use of optical filters at the saturation region of the OASLM. For purposes of beam widening, an optical imaging system

[is]can be preferably inserted into the optical path of rays, within which the OASLM is located. The optical imaging system [preferably]can encompas[se]s two telescope imaging systems, preferably designed as mechanically or electrically adjustable or controllable zoom systems. Thus, the beam widening [is]can be variable, so that changes in intensity can always be compensated by intensity fluctuations of the laser or by replacing the laser.

Brief [d]Description of the [drawing, illustrating:]Drawings

Figure 1[ ] shows a typical transmission characteristic of an OASLM[

Figure 2 three set-ups according to] in accordance with the present invention;

Figure 2a shows an embodiment of the present invention for forming a beam with the use of an OASLM;

Figure 2b shows another embodiment of the present invention for forming a beam with the use of an OASLM; and

Figure 2c shows another embodiment of the present invention for forming a beam, with the use of an OASLM.

Detailed Description

Figure 1 schematically depicts a typical transmission characteristic of an OASLM, as used in accordance with the present invention, the incident intensity being plotted on the x-axis and the transmitted intensity on the y-axis. For low intensities, the OASLM has a substantially linear transmission characteristic, for

example, it is essentially transparent to the incident radiation. For higher incident intensities, the transmitted intensity is substantially independent of the incident intensity; this saturation range is selected as the working range for the beam formation. The intensity of the incident laser beam to be formed [is]can be adapted to this working range by filters or by widening the beam. In this context, [the advantage of]by widening the beam[is that], once it has passed through the OASLM, the light is able to be focused again[, so that] and there is minimal loss of total intensity.

Three set-ups are shown in Figures 2a-c for forming a beam in accordance with the present invention, using an OASLM. Figure 2a illustrates a set-up where the OASLM is inserted between two coupler telescopes 1, 2, into the laser's path of rays. Telescopes 1, 2 each include two lenses having focal lengths f_1, f_2 and f_1', f_2', respectively, arranged at a distance of f_1+f_2 and $f_1'+f_2'$, respectively. The telescopes [are]can be used for beam widening, to reduce the intensity in the laser beam center to the point where it coincides with the plateau region of the characteristic in accordance with Figure 1. The laser beam having the flattened beam profile exits the second telescope 2 to the right. If it is necessary to simultaneously widen the beam, the right telescope 2 must have a smaller magnification than the left telescope 1.

In certain cases, for example, once a laser is coupled into an optical fiber, the laser intensity can already be optimally adapted to the OASLM. Without any previous widening, the light can then be directly conducted to the OASLM, as shown in Figure 2b. The light from fiber 3 then falls directly on beam former OASLM, which can be in

optical contact with fiber 3. Reflection losses experienced during the transition into the OASLM, are able to be kept to a minimum in this case by using an oil to adapt the refraction index. [The advantage of this specific embodiment is that]Thus the OASLM can have an especially small type of construction in this embodiment of the present invention.

When [one is experiencing]heavy fluctuations in laser intensity is being experienced, or when the intention is to use the same beam former for different types of lasers, it is recommended to connect two zoom telescopes 5, 6 instead of telescopes having fixed magnifications, as in Figure 2a. [T]A possible embodiment of this is shown schematically in Figure 2c. In this case, the beam widening can be altered and, given electrically adjustable zoom telescopes, also controlled.

[Industrial Applicability

]The present invention has many diverse industrial applications. [In particular, it is advantageously]The present invention can be employed in applications where the most uniform possible illumination of surfaces by laser light is critical, especially when working with image processing and projection technology, in interferometry, as well as in material processing where the use of lasers is required.

[

]

[
]Abstract

The present invention relates to a method and a device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile. In an embodiment of the present invention, the laser beam [striking] can strike an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity.[By using an OASLM of this kind, a beam former is created, which, in principle, without any additional external influence, automatically generates a virtually rectangular beam profile, which is independent of fluctuations in the initial intensity distribution and is suited for use in any laser system at all.]

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[2345/144]

METHOD AND DEVICE FOR FORMING THE INTENSITY PROFILE OF A LASER BEAM

Technical Field

The present invention relates to a method and a device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, as well as to the use of an optically addressable spatial light modulator (OASLM) for forming the intensity profile of a laser beam.

Background of the Invention

The physical properties of laser light differ fundamentally from those of conventional light sources. Laser light is coherent and can be produced as a light beam having a small, even if finite aperture angle. This narrow beam concentration is particularly advantageous for illumination and imaging purposes, since the wave fronts of the laser light approach the ideal of plane waves. They are very easily transformed into spherical wave fronts and can be utilized for highly resolving, diffraction-limiting focusing.

One drawback of the laser beam is its Gaussian character, which is determined by the manner in which light is generated in the resonator. The intensity distribution of the light transversely to the beam has the shape of a Gaussian bell curve. This means that the intensity is at a maximum in the middle of the beam, and it then drops off exponentially toward the edges.

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This is particularly disadvantageous in image processing and projection technologies which require illuminating flat photomasks. However, it is also a drawback in interferometry, where a most uniform possible illumination of the lighted surface is critical. Such uniformity is not provided when working with a Gaussian intensity profile. In material processing as well, such as in medical applications involving heating of tissue, or in laser welding, uniform heating is required over the entire width of the laser beam or of the illuminated surface. Such uniform heating cannot be attained when working with a Gaussian shaped illumination and, thus, for instance a Gaussian energy deposition. For that reason, the cross-sectional profile of the light beam should be as rectangular as possible for the areas of application mentioned. The spatial intensity profile should be homogeneous, i.e., more or less constant over a certain width. To effect this, in practice, the beam is widened and one then works only with the more or less homogeneous, inner beam region, the outer region being masked out. However, this leads to significant intensity losses.

Since the actual laser system, the optical amplification medium in the resonator, is not accessible to the user, the forming of the beam into a rectangular profile must take place outside of the laser. For this purpose, optical filters, so-called "bull's eye" filters are known, which attenuate the laser beam more vigorously in the middle than at the edges, thereby flattening the bell shape of the beam profile to a virtually rectangular profile. For the most part, these filters are made of a

transparent plate, e.g., a glass plate, upon which a more or less reflective coating, for example a metal, is coated by vapor deposition. The desired beam profile is produced by properly selecting the locally dependent optical density, i.e., the local transmission and reflection properties. These filters are static and, therefore, can only be used for a specific laser having a fixed, known intensity profile. When the laser changes its profile, e.g., due to fluctuations or manifestations of aging, the filters undesirably alter the shape of the profile, since they are no longer adapted to the laser data. Another disadvantage associated with reflecting filters of this kind is that unevenly reflected laser light has a reactive effect on the laser and can degrade its stability. Moreover, in place of reflecting filters, it is also generally known to use holographic filters for forming beams (I. Gur et al.: Diffraction limited domain flat-top generator; Opt. Communications 145, 237 (1998)). These filters are also static and are not responsive to time-related changes in the laser beam profile. Also problematic is the fact that the rectangular profile is only produced in the imaging plane of the holographic element.

Technical Objective

The underlying objective of the present invention is, therefore, to form the most homogeneous possible, rectangular beam profile from any initial intensity profile at all, in particular from a Gaussian beam profile, the intention being for the formed beam profile to be substantially stable with respect to fluctuations

in the incident intensity profile and in the light intensity.

Detailed Description of the Invention

The objective is achieved by a method for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, the laser beam striking an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity.

A device in accordance with the present invention for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, is composed of an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity, as well as of at least one telescope imaging system, which is capable of spatially widening the laser beam.

Furthermore, the objective is achieved by the use of an optically addressable spatial light modular (OASLM) for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile.

The present invention provides a beam former, i.e., a method for forming beams, where the formed intensity profile is stabilized with respect to changes in the original intensity profile through the use of an active

or adaptive optical element having optical properties that are dependent upon the local illumination intensity. In particular, an optical element is used, whose local transparency changes with the local illumination intensity. A defined beam profile, which is virtually independent of fluctuations in the initial intensity distribution, is automatically produced. In principle, this is done without any additional controlling external influence. For that reason, the method and the beam former, respectively, can be used for any laser systems at all, and only need to be adapted to a minor degree to prevailing conditions.

In accordance with the present invention, the optically non-linear element is an optically addressable spatial light modulator (OASLM) or liquid crystal light valve. It is preferably driven in the saturation range to produce a homogeneous (rectangular) laser beam profile; the locally transmitted intensity is then independent of the local illumination intensity.

Optically addressable spatial light modulators (OASLM) are known, for example, from "Spatial Light Modulators; OSA - Technical Digest ISBN 155752-494-7 Washington 1997" which are made of a photoconductive layer and of an electro-optical, voltage-sensitive layer. In response to local irradiation, the voltage in the photoconductor breaks down locally and is transferred to the electro-optical layer. On a localized basis, this alters the transmission or reflection characteristics of the electro-optical layer, which, in turn, is now optically indicative of the irradiation. The photoconductive layer

must be sensitive to the wavelength of the incident light. The electro-optical layer is, for example, a liquid crystal, which has optical modulator properties within broad spectral ranges. Certain materials unite the properties of the photo-sensitive and voltage-sensitive layer, such as photorefractive crystals or polymers (Spatial Light Modulators; OSA - Technical Digest ISBN 155752-494-7 Washington 1997, M. Petrov et al.: Photorefractive Crystals, Berlin 1991).

In accordance with the present invention, liquid crystals which have nonlinear optical properties are used in OASLMs. The OASLM is based, for example, on nematic or helical smectic liquid crystals, the latter having an operating frequency of 10^2 to 10^3 Hz, thereby facilitating faster reactions to output profile changes than do elements based on nematic liquid crystals (switching times in the range of 10^{-2} s). The modulation properties of these liquid crystals depend nonlinearly on the applied voltage and, thus, on the local illumination intensity 1 on the photoconductor.

A typical transmission characteristic of an OALSM of this kind is exemplified by a linear relation between the illumination intensity and transmitted intensity for low illumination intensities, as well as by a transition into the saturation range, where the transmitted intensity is virtually independent of the illumination intensity. For higher intensities, the transmitted intensity can again depend more heavily on the illumination intensity.

The above described properties of an OASLM enable, in

particular, high light intensities to be attenuated more vigorously than low intensities. In this manner, the intensity of a Gaussian beam in the center is suppressed as compared to the edge regions, and the transmitted intensity approaches a rectangular shape having a flat plateau in the center.

One advantageous further refinement of the present invention provides for the OASLM layers to undergo pattern delineation, preferably resolved into individual zones, in particular optical points (pixels), preferably capable of being driven individually. This diminishes crosstalk between nearby picture elements. Finally, this permits electrical intervention in the modulator, on a pixel-by-pixel basis, in particular an adaptation of the local transmission properties, targeted to the initial intensity profile. One can advantageously regulate the driving of the individual zones by measuring the shaped beam profile and examining it for deviations from a nominal form, in particular from the rectangular form. By way of a feedback path, the magnitude of the local deviations is then used as a basis for adapting the transmission properties of the zones or of the picture elements of the OASLM.

To work in the saturation region of the OASLM, the intensity of the laser beam to be shaped is preferably adapted by widening the beam and/or through the use of optical filters at the saturation region of the OASLM. For purposes of beam widening, an optical imaging system is preferably inserted into the optical path of rays, within which the OASLM is located. The optical imaging

system preferably encompasses two telescope imaging systems, preferably designed as mechanically or electrically adjustable or controllable zoom systems. Thus, the beam widening is variable, so that changes in intensity can always be compensated by intensity fluctuations of the laser or by replacing the laser.

Brief description of the drawing, illustrating:

Figure 1 a typical transmission characteristic of an OASLM

Figure 2 three set-ups according to the present invention for forming a beam, with the use of an OASLM

Figure 1 schematically depicts a typical transmission characteristic of an OASLM, as used in accordance with the present invention, the incident intensity being plotted on the x-axis and the transmitted intensity on the y-axis. For low intensities, the OASLM has a substantially linear transmission characteristic, for example, it is essentially transparent to the incident radiation. For higher incident intensities, the transmitted intensity is substantially independent of the incident intensity; this saturation range is selected as the working range for the beam formation. The intensity of the incident laser beam to be formed is adapted to this working range by filters or by widening the beam. In this context, the advantage of widening the beam is that, once it has passed through the OASLM, the light is able to be focused again, so that there is minimal loss of total intensity.

Three set-ups are shown in Figures 2a-c for forming a

beam in accordance with the present invention, using an OASLM. Figure 2a illustrates a set-up where the OASLM is inserted between two coupler telescopes 1, 2, into the laser's path of rays. Telescopes 1, 2 each include two lenses having focal lengths f_1, f_2 and f_1', f_2', respectively, arranged at a distance of f_1+f_2 and $f_1'+f_2'$, respectively. The telescopes are used for beam widening, to reduce the intensity in the laser beam center to the point where it coincides with the plateau region of the characteristic in accordance with Figure 1. The laser beam having the flattened beam profile exits the second telescope 2 to the right. If it is necessary to simultaneously widen the beam, the right telescope 2 must have a smaller magnification than the left telescope 1.

In certain cases, for example once a laser is coupled into an optical fiber, the laser intensity can already be optimally adapted to the OASLM. Without any previous widening, the light can then be directly conducted to the OASLM, as shown in Figure 2b. The light from fiber 3 then falls directly on beam former OASLM, which can be in optical contact with fiber 3. Reflection losses experienced during the transition into the OASLM, are able to be kept to a minimum in this case by using an oil to adapt the refraction index. The advantage of this specific embodiment is that the OASLM can have an especially small type of construction.

When one is experiencing heavy fluctuations in laser intensity, or when the intention is to use the same beam former for different types of lasers, it is recommended to connect two zoom telescopes 5, 6 instead of telescopes

having fixed magnifications, as in Figure 2a. This is shown schematically in Figure 2c. In this case, the beam widening can be altered and, given electrically adjustable zoom telescopes, also controlled.

Industrial Applicability

The present invention has many diverse industrial applications. In particular, it is advantageously employed in applications where the most uniform possible illumination of surfaces by laser light is critical, especially when working with image processing and projection technology, in interferometry, as well as in material processing where the use of lasers is required.

Patent Claims

1. A method for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, the laser beam striking an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity.

2. The method as recited in Claim 1, characterized in that the transmission or reflection characteristic of the OASLM has a saturation range, in which the locally transmitted or reflected intensity is substantially independent of the locally incident intensity, this saturation range being selected as the working range.

3. The method as recited in Claim 2, characterized in that the intensity of the laser beam to be formed is adapted to the saturation range of the OASLM by widening the beam and/or by optical filters.

4. The method as recited in Claim 2 or 3, characterized in that for purposes of beam widening, an optical imaging system is inserted into the optical path of rays, within which the OASLM is located.

5. The method as recited in Claim 4, characterized in that the optical imaging system encompasses two telescope imaging systems (1, 2, 5, 6), designed as

mechanically or electrically adjustable or controllable zoom systems, the beam widening thus being variable, in particular, adaptable to changes in intensity.

6. The method as recited in one of Claims 1 through 5, characterized in that the OASLM is a liquid crystal modulator.

7. The method as recited in one of Claims 1 through 6, characterized in that the OASLM is partitioned into individual zones, which are able to be electrically driven as separate zones to alter the local transmission and/or reflection properties of the OASLM.

8. A device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, comprising an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity, as well as at least one telescope imaging system, capable of spatially widening the laser beam.

9. The device as recited in Claim 8, characterized in that the OASLM is a liquid crystal modulator.

10. The device as recited in Claim 8 or 9, characterized in that the OASLM is partitioned into individual zones, which are able to be electrically driven as

separate zones to alter the local transmission and/or reflection properties of the OASLM.

11. A use of an optically addressable spatial light modulator (OASLM) for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile.

Abstract

The present invention relates to a method and a device for forming the intensity profile of a laser beam, in particular for producing a homogeneous intensity profile, the laser beam striking an optically addressable spatial light modular (OASLM), whose local transmission or reflection properties depend in nonlinear fashion on the local illumination intensity. By using an OASLM of this kind, a beam former is created, which, in principle, without any additional external influence, automatically generates a virtually rectangular beam profile, which is independent of fluctuations in the initial intensity distribution and is suited for use in any laser system at all.

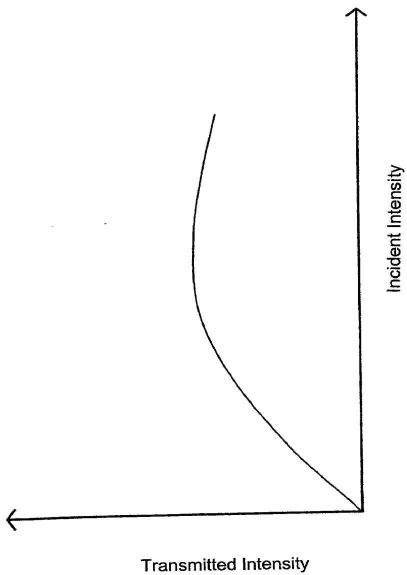

FIG. 1

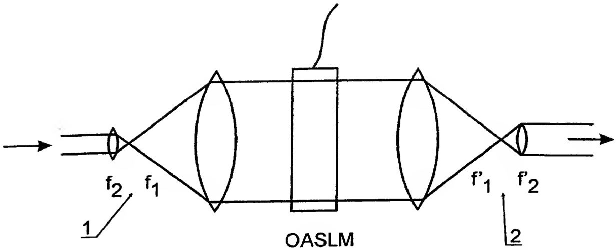

Fig. 2a).

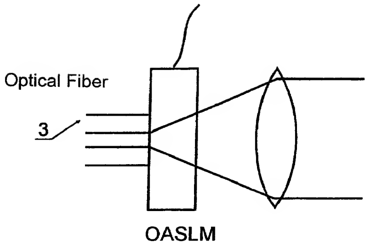

Fig. 2b).

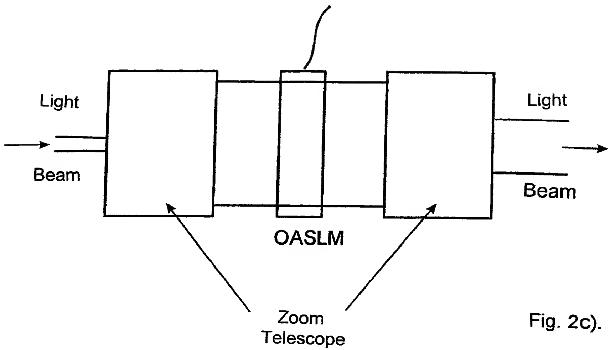

Fig. 2c).

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD AND DEVICE FOR FORMING THE INTENSITY PROFILE OF A LASER BEAM**, the specification of which was filed as International Application No. PCT/EP00/05367 on June 10, 2000 and filed as a U.S. application having Serial No. 09/786,837 for Letters Patent in the U.S.P.T.O.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

Number	Country Filed	Day/Month/Year	Priority Claimed Under 35 USC 119
199 31 989.8	Fed. Rep. of Germany	9 July 1999	Yes

And I hereby appoint Richard L. Mayer (Reg. No. 22,490), Gerard A. Messina (Reg. No. 35,952) and Linda M. Shudy (Reg. No. 47,084) my attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful and false statements may jeopardize the validity of the application or any patent issued thereon.

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